

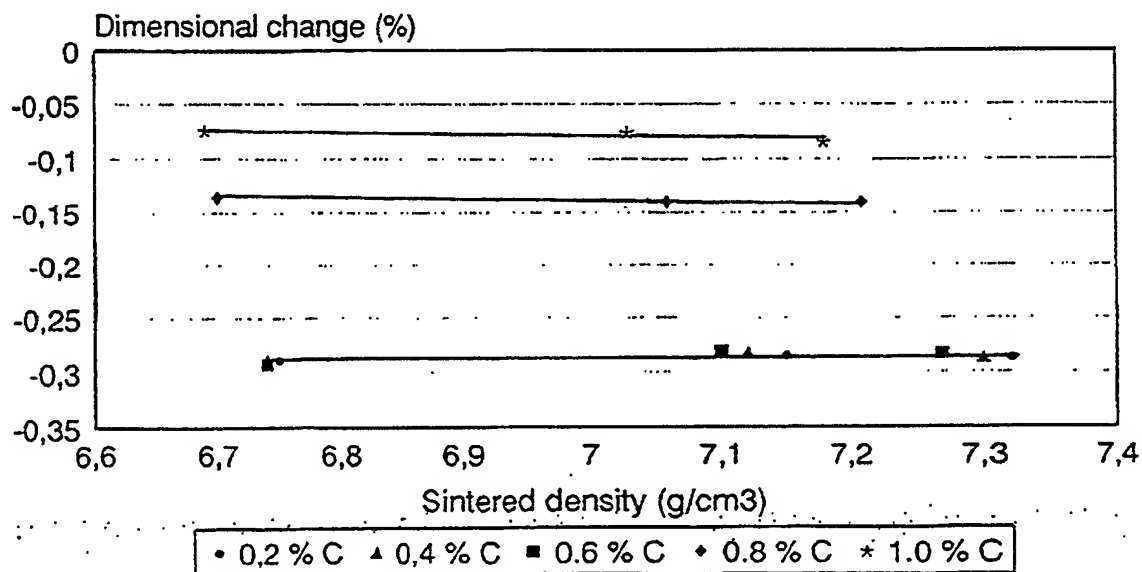


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>5</sup> : B22F 1/00, C22C 33/02	A1	(11) International Publication Number: WO 94/13418 (43) International Publication Date: 23 June 1994 (23.06.94)
(21) International Application Number: PCT/SE92/00860 (22) International Filing Date: 11 December 1992 (11.12.92)  (71) Applicant (for all designated States except US): HÖGANÄS AB [SE/SE]; S-263 83 Höganäs (SE). (72) Inventors; and (75) Inventors/Applicants (for US only): LINDBERG, Caroline [SE/SE]; Travgatan 5, S-263 36 Höganäs (SE). JOHANSSON, Björn [SE/SE]; Långgatan 19, S-263 32 Höganäs (SE). (74) Agent: AWAPATENT AB; P.O. Box 5117, S-200 71 Malmö (SE).		(81) Designated States: BR, CA, JP, KR, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published With international search report. With amended claims.

(54) Title: IRON-BASED POWDER COMPOSITION

Dimensional change as a function of sintered density  
Material C at different carbon contents



(57) Abstract

An iron-based powder for producing high-strength components with a small local variation in dimensional change, by powder compacting and sintering. The powder contains, in addition to Fe, 0.5-4.5 % by weight Ni, 0.65-2.25 % by weight Mo and 0.20-1.0 % by weight C, and optionally a lubricant and impurities.

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IRON-BASED POWDER COMPOSITION

The present invention relates to an iron-based powder which after powder compacting and sintering gives dimensionally stable products, i.e. products inherently exhibiting similar dimensional changes, also in the event of  
5 local density variations.

A major advantage of powder-metallurgical processes over conventional techniques is that components of varying complexity can be sintered into final shape immediately after powder compacting, and they therefore require but a  
10 relatively limited aftertreatment as compared with e.g. a conventional steel blank. Also in the development of new powder-metallurgical materials, it is an aim to ensure that the dimensional change is small during sintering, since it has been found difficult in practice to maintain  
15 the dimensional stability if the dimensional change is considerable. This is especially important in the case of high-strength materials which are difficult to adjust to correct measurement after sintering. Therefore, it is vital that the dimensional change is minimal and as independent as possible of variations in the process parameters sintering time, sintering temperature, carbon content and distribution of alloying substances. In the development of high-strength diffusion-alloyed materials  
20 during the 1970s, the primary objective precisely was to make the dimensional change as independent as possible of these process variables.

By the diffusion-alloying technique, the alloying substances Ni, Cu and Mo have become uniformly distributed in the material and the contents of these substances can  
30 be so selected that variations in the other process parameters time, temperature and C-content have but a small effect on the dimensional change. On the other hand, it has been found that the dimensional change is not constant for different density levels in these materials. In the  
35 compaction of powder mixtures, the density may in fact

vary considerably within the compacted component and in particular if the geometrical shape is complex. This, in turn, may give rise to different dimensional changes locally during sintering, thus making the material "warp", which may mean that it will have to be rejected.

The invention is based on the discovery that, during the sintering process, green products made of the powder compositions according to the invention undergo essentially the same dimensional change in spite of density variations within the green products. Thus, for a density variation of e.g.  $0.3 \text{ g/cm}^3$  within the green product, this means that, during the sintering process, the difference in expansion/contraction between parts of the green body having a density of about  $6.8 \text{ g/cm}^3$ , and parts having a density of about  $7.1$  is at most about  $0.042\%$ . In view hereof, the compact of the powder composition according to the invention is "dimensionally stable" within the density range  $6.7\text{--}7.5 \text{ g/cm}^3$ . Naturally, the powder compositions are dimensionally stable also for smaller variations within this range. It should however be noted that the overall dimensional change during the sintering process may vary as in conventional processes, but by using the composition according to the present invention, the pressing tools can be adjusted in size already at the design stage so as to obtain the correct shape after sintering.

The powder compositions according to the invention are especially suited for producing products having complex or irregular shape, in which density variations occur during the compacting process. Of course, the powders are also suited for producing sintered products in which less or no density variations at all exist within the green product. However, already when sintering green bodies having a density variation as small as  $0.1 \text{ g/cm}^3$ , the advantage of using the present compositions is obvious, leading to a variation in the dimensional change of at most  $0.014\%$ . The advantages of using the powder compositions

according to the invention are of course greater when the density variations are above 0.2 or 0.3 g/cm<sup>3</sup> within the green product.

Another way of expressing the properties of the iron powder according to the invention is that it should satisfy the condition

$$\frac{\Delta dL}{\Delta SD} \leq 0.14$$

wherein  $\Delta dL$  is the variation in the dimensional change (%) within the sintered product measured from the green to the sintered condition, and  $\Delta SD$  is the variation in the density (g/cm<sup>3</sup>) within the sintered product.

Another object of the invention is to produce an iron-powder-based material which after compacting and sintering yields a dimensionally stable product having high strength. For instance, it is possible with the iron-powder-based material according to the invention to produce sintered products having a tensile strength above about 450 MPa, especially between 500 and 1000 MPa, and preferably between 550 and 950 MPa, without the sintered product being subjected to subsequent heat treatment. At a sintered density of e.g. 6.8 g/cm<sup>3</sup>, the sintered products according to the invention exhibit a tensile strength exceeding 500 MPa, which is considered a high tensile strength.

Yet another object of the invention is to produce a powder which by a simple and inexpensive low-temperature sintering process yields a product having the properties specified above.

The invention embraces also such powders as after compacting and sintering exhibit not only good dimensional stability and high strength but also high fatigue strength. In these powders, the nickel content is comparatively high and preferably is in the range of 2-4.5% by weight.

According to the invention, these objects can be achieved by a powder composition which, in addition to iron, includes 0.5-4.5% by weight of nickel, 0.65-2.25% by weight of molybdenum, and 0.20-1.0% by weight of carbon. In the copending application PCT/SE92/00399, which is hereby incorporated by reference, iron powder compositions having a C-content between 0.35 and 0.65% are described and, thus, the present invention particularly relates to compositions outside this range. The invention is also directed to products produced from the stated compositions, and to a method for producing the products on the basis of the compositions. Moreover, the invention relates to the use of the powder compositions for producing sintered products. The other features of the invention are recited in the accompanying claims.

Compositions containing the components Fe, Ni and Mo in approximately the same contents as in the present invention are previously known from EP 0,334,968. These known compositions are intended for use in the making of products which after sintering and heat treatment (quenching and tempering) are distinguished by a very high strength and high hardness. However, the EP publication does not contain any information or indication whatever of any particular advantages of these powder compositions when it comes to producing dimensionally stable and high-strength products obtained by simple sintering without any subsequent heat treatment. Since it is well-known that the dimensional accuracy is impaired in heat treatment, it is not possible by using the method disclosed in EP 0,334,968 to achieve the object of the present invention.

DOS 2,112,944 also discloses powder compositions including Ni and Mo in such amounts as to place the present powder compositions within the ranges here suggested. However, the compositions of DOS 2,112,944 also include Mn as a compulsory component, whereas any Mn present in the powder composition according to the invention is an undesirable impurity. Consequently, it is preferred according

to the present invention that the content of Mn is at a minimum and less than 0.3% by weight, preferably less than 0.1% by weight. The DOS publication further mentions Ni, Mn, Mo and Fe as completely prealloyed powders. Reference is also made to DE 1,207,634, in which Ni and/or Mo and/or Mn is/are added to an iron base powder, either as pure substances, or as master alloys (which means that at least two of the included alloying substances form a chemically homogeneous powder) or as ferro-alloy powder (chemically homogeneous material in which iron is included, but with essentially higher alloying contents as compared with the material of the invention). These variants of powder mixtures are not comprised by the present invention. Nor do these publications teach or suggest anything whatever about the advantages that can be gained with the invention.

The powder compositions according to the invention have proved well suited for use in so-called low-temperature sintering, which means sintering at temperatures below about 1150°C. Such sintering may advantageously be performed in belt furnaces. Sintering in such furnaces usually takes place at temperatures of about 1120°C-1140°C for at most 1 hour, generally between 20 and 40 min. Before the powder compositions are passed into the sintering furnace, they are first admixed with a lubricant and thereafter moulded in a pressing tool under high pressure. For highly resistant products, the compacting pressure is in practice about 600 MPa.

For the powder compositions according to the invention, preference is given to such powders in which the nickel content varies between 1.0 and 3.0% by weight and the molybdenum content varies between 0.8 and 2.0% by weight. The best results have hitherto been achieved with compositions in which the content of Ni > the content of Mo, and particularly preferred are compositions containing 1.5% by weight of molybdenum and about 2% by weight of nickel. For products requiring higher fatigue strength,

the amount of nickel should be higher, preferably between 2 and 4% by weight.

In addition to the indicated substances, the powder compositions may contain impurities, the content of which should be as low as possible. Examples of impurities in the compositions according to the invention are copper, tungsten and phosphorous, which interfere with the dimensional stability. Other impurities that may also have an adverse effect on the sintered product because of oxidation are chromium, manganese, silicon and aluminium. The total content of impurities should be maintained below 2% by weight, preferably below 1% by weight. In addition, the powder composition of the invention may optionally contain a lubricant of the type which is known to those skilled in the art. In a particularly preferred embodiment, Mo is present in solid solution in a water-atomised iron-based powder. This embodiment provides a powder which imparts to the sintered components a more homogeneous structure on micro level as compared with powders in which Mo is not prealloyed to the iron. At the same time, the sintered density is affected only insignificantly when Mo is prealloyed to the iron. If, on the other hand, Ni is present in solid solution in the iron-based powder, the compressibility of the material is impaired, as is also the sintered density (the Example below shows, for instance, how material B in Table 2 will have a very low density after sintering at the compacting pressures used as compared with the other materials. This material includes about 2% Ni and 0.5% Mo as prealloyed elements in the iron-based powder while material A, which also is completely prealloyed but with about 1.5% Mo, will have a much higher density after sintering under the same process conditions as for material B). Therefore, Ni preferably is in metallic form, it being diffusion-alloyed with the iron-based powder prealloyed by means of Mo. Ni may also in this case be mixed with the prealloyed powder.



The alloying content ranges are selected under the consideration that the material of the invention should satisfy at least three of the conditions stated above, viz., within the limits specified, provide a dimensionally stable sintered product despite varying density levels within the product, provide an iron-powder-based material which after compacting and sintering yields a dimensionally stable product having high strength, and provide a powder which by simple and inexpensive low-temperature sintering without subsequent heat treatment can yield a product having the properties specified above.

The accompanying Figs 1-4 show how the dimensional change varies at different density levels during sintering, and how the tensile strength is affected by the sintered density at different contents of alloying substances Ni, Mo and C. These Figures show compacted and sintered powder mixtures where Mo (if present) has been prealloyed in an atomised iron-based powder having a particle size substantially below 200  $\mu\text{m}$ , while Ni (if present) having a particle size substantially below 15  $\mu\text{m}$  has thereafter been diffusion-alloyed to the iron-based powder. C in the form of graphite having a particle size substantially below 15  $\mu\text{m}$  has thereafter been added to the powder. The powder mixtures have then sintered in a belt furnace at 1120-1140°C for 30 min in endothermic atmosphere at a carbon potential corresponding to the carbon content of the material.

Fig. 1a shows how the tensile strength is improved at increasing density and Ni-content, while Fig. 1b shows how the dimensional change is similar at different density levels for the material of the invention. A too high or a too low Ni-content, i.e., falling outside the stated limits of the inventive material, results in too large variations in dimensional change at different density levels. Fig. 2a illustrates how an increased carbon content improves the tensile strength, while Fig. 2b shows that also iron-powder compositions having a carbon con-

tent of up to 1% by weight give a low variation in dimensional change at different density levels. Figs 3a and b show that a certain Mo-content is required to meet the requirements as to strength and similar dimensional change at densities above  $6.7 \text{ g/cm}^3$ .

Fig. 4 shows that also for densities of up to  $7.5 \text{ g/cm}^3$ , the powder composition according to the invention gives small dimensional changes. Composition C according to the invention includes 0.5% carbon. In this context, it should be mentioned that densities above about  $7.3 \text{ g/cm}^3$  to  $7.5 \text{ g/cm}^3$  can be obtained by subjecting the compacted green product to a presintering step at a temperature between  $700$  and  $850^\circ\text{C}$ . The presintered product is then compacted once more before the final sintering step.

The invention will be illustrated by the Example below. This Example is intended merely to illustrate an embodiment of the invention in a non-restrictive manner.

#### Example

Two different powders (A, B) were prepared by water-atomising an iron melt alloyed both with Mo and with Ni. The oxygen content was reduced by annealing the atomised powders in reducing atmosphere. In addition, Ni was diffusion-annealed in reducing atmosphere in two contents to the iron-based powder which was prealloyed with Mo (C, D). A non-alloyed iron powder was also prepared by water-atomisation and annealed to reduce the oxygen content. The resulting powder was thereafter diffusion-annealed with different amounts of Mo, Ni and Cu (E, F, G, H). The chemical composition of the different powders appears from Table 1 below.

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	Powder	Chemical composition (%)			
		Ni	Mo	Cu	Fe
	A	-	1.51	-	balance
	B	1.92	0.48	-	balance
5	C*	1.98	1.52	-	balance
	D*	2.97	1.50	-	balance
	E*	2.01	1.48	-	balance
	F	3.92	0.54	1.47	balance
	G	3.99	0.53	-	balance
10	H	1.72	0.53	1.47	balance

\* powder according to the present invention.

Table 1. Chemical composition of the powder materials tested.

15       The different powders having a particle size substantially below 200  $\mu\text{m}$  were admixed with 0.5% graphite having a particle size substantially below 15  $\mu\text{m}$  and 0.6% Kenolube as lubricant. After mixing, tensile testpieces were compacted at 400, 600 and 800 MPa. Sintering was  
 20 performed at 1120°C for 30 min in reducing atmosphere (endogas) at a carbon potential of 0.5%. Methane was added to control the carbon content. After sintering, the tensile strength and the dimensional change were measured for the different materials at varying densities. The  
 25 result appears from Table 2 below.

		10		
	Material	Tensile strength (MPa)	Sintered density (g/cm <sup>3</sup> )	Dimensional change (%)
5	A	400	6.67	-0.03
		540	7.05	-0.01
		602	7.22	-0.01
	B	346	6.55	-0.37
		458	6.98	-0.33
		528	7.19	-0.32
10	C*	597	6.75	-0.38
		727	7.10	-0.36
		785	7.27	-0.37
	D*	640	6.79	-0.53
		796	7.13	-0.50
		877	7.30	-0.49
15	E*	591	6.75	-0.21
		696	7.08	-0.19
		774	7.24	-0.18
	F	699	6.80	-0.37
		855	7.11	-0.26
		895	7.25	-0.24
20	G	578	6.84	-0.27
		694	7.14	-0.22
		757	7.32	-0.18
	H	519	6.81	-0.18
		620	7.11	-0.12
		655	7.30	-0.09
25				

\* Material according to the present invention.

Table 2. Tensile strength and dimensional change at varying densities.

Materials A, B, F and H are previously known, and as appears from the Table, material F gives high strength, but a relatively large variation in dimensional change at different densities. Material G has been produced in the same way, but without addition of Cu. The strength value has therefore dropped, but still is quite acceptable. On the other hand, the variation in dimensional change still is too high in the density range exceeding 6.7 g/cm<sup>3</sup>. By

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lowering the Ni-content in material F from about 4% by weight to about 1.75% by weight (= material H), the variation in dimensional change at different densities decreases, but still is too high. The prealloyed materials A and B exhibit a small variation in dimensional change at different densities, but the strength values are too low.

However, it has been found that the combination of a higher Mo-content than in material B, with an Ni-addition gives a material having high strength and a small variation in dimensional change at different densities. As appears from Table 2, the properties become similar in materials C and E, whether Mo is prealloyed (i.e. is added before atomisation) or it is diffusion-alloyed. The only difference is the level of dimensional change, which does not conflict with the invention. Adding more Ni (material D) gives improved strength, but a slightly higher variation in dimensional change than for materials C and E. The variation in dimensional change at different densities however is in compliance with the requirements of the invention.

## CLAIMS

1. Iron-based powder composition for producing dimensionally stable high-strength sintered products, characterised in that the powder of the green product, in addition to iron, essentially consists of

- 5                   0.5 - 4.5 % by weight Ni  
                  0.65 - 2.25 % by weight Mo  
                  0.20 - 1.0 % by weight C,

less than about 2% by weight, preferably less than about 1% by weight, of impurities and optionally lubricant.

- 10       2. Composition according to claim 1, wherein it comprises more than 0.65% by weight C, or from 0.20 to less than 0.35% by weight C.

3. Composition according to claim 1 or 2, wherein Mo, and optionally Ni, is present in solid solution in an atomised iron powder.  
15

4. Composition according to any of claims 1-3, wherein Ni is present in metallic form.

5. Method of producing a high-strength sintered body without subsequent heat treatment, comprising the steps of

- 20       a1) preparing an iron powder and diffusion-alloying Ni and/or Mo to the iron powder or mixing metal particles of Ni and/or Mo to the iron powder, or  
a2) preparing a melt of iron and molybdenum, water-atomising the melt to a powder and diffusion-alloying  
25       Ni to the resulting powder or mixing metal particles of Ni with the powder,  
b) adding carbon to the powder obtained, the amount of the included components being so selected that the resulting powder composition is dimensionally stable  
30       and, in addition to iron, essentially consists of about

- 0.5 - 4.5 % by weight Ni  
0.65 - 2.25 % by weight Mo  
0.20 - 1.0 % by weight C,

less than 2% by weight, preferably less than about 1% by weight, of impurities and optionally lubricant, c) compacting the powder composition, and d) sintering the compacted powder composition.

5        6. Method according to claim 5, wherein the powder comprises from 0.20 to less than 0.35 or more than 0.65% by weight C.

7. Method according to claims 5 and 6, wherein, for densities above about  $7.3 \text{ g/cm}^3$ , the green product is sub-  
10        jected to presintering and an additional compacting step before the final sintering step.

8. Method according to claim 7, wherein the presintering step is carried out at a temperature between 700 and  $850^\circ\text{C}$ .

15        9. Method according to claim 5 or 6, wherein the compacted powder composition is subjected to a final sintering at a temperature between about  $1070^\circ\text{C}$  and about  $1150^\circ\text{C}$ , preferably between  $1100^\circ\text{C}$  and  $1140^\circ\text{C}$ .

10        10. Method according to any of claims 5-7 for producing sintered products having a tensile strength of 500-1000 MPa without subsequent heat treatment.

11. Use of an iron-powder composition for the production of dimensionally stable high-strength sintered products, c h a r a c t e r i s e d in that the powder com-  
25        position, in addition to iron essentially consists of

0.5 - 4.5 % by weight Ni

0.65 - 2.25 % by weight Mo

0.20 - 1.0 % by weight C,

less than about 2% by weight, preferably less than about  
30        1% by weight, of impurities and optionally lubricant.

12. Use according to claim 9, wherein the powder composition includes from 0.20 to less than 0.35 or more than 0.65% by weight of carbon.

## AMENDED CLAIMS

[received by the International Bureau on 25 August 1993 (25.08.93);  
original claims 1-12 replaced by amended claims 1-15 (5 pages)]

1. Iron-based powder composition which in addition  
to iron essentially consists of
  - 5           0.5 - 4.5 % by weight Ni
  - 0.65 - 2.25 % by weight Mo
  - 0.20 - 1.0 % by weight C,less than about 2% by weight, preferably less than about  
1% by weight, of impurities and optionally lubricant,  
10 characterised in that the composition gives essentially  
the same variation in the dimensional change irrespec-  
tive of density variations within the range of 6.7-7.5  
g/cm<sup>3</sup> in the green body.
2. Iron powder composition which in addition to  
15 iron essentially consists of
  - 0.5 - 4.5 % by weight Ni
  - 0.65 - 2.25 % by weight Mo
  - 0.20 - 1.0 % by weight C,less than about 2% by weight, preferably less than about  
20 1% by weight, of impurities and optionally lubricant,  
except for the powder compositions C, D, E and N of  
EP-334 968 and powder A of EP-200 691.
3. Composition according to claim 1 or 2, wherein  
Mo and optionally Ni is present in solid solution in an  
25 atomised iron powder.
4. Composition according to claim 3, wherein Ni is  
present in metallic form.
5. Method of producing a high-strength sintered  
body, comprising the steps of
  - 30       a1) preparing an iron powder and diffusion-alloying  
          Ni and/or Mo to the iron powder or mixing metal  
          particles of Ni and/or Mo to the iron powder, or



- 5 a2) preparing a melt of iron and molybdenum, water-atomising the melt to a powder and diffusion-alloying Ni to the resulting powder or mixing metal particles of Ni with the powder,
- b) adding carbon to the powder obtained, the amount of the included components being so selected that the resulting powder composition in addition to iron essentially consists of about
- 10 0.5 - 4.5 % by weight Ni  
0.65 - 2.25 % by weight Mo  
0.20 - 1.0 % by weight C,  
less than 2% by weight, preferably less than about 1% by weight, of impurities and optionally lubricant,
- 15 c) compacting the powder composition for obtaining a green body, and  
d) sintering the green body at a temperature below 1150°C, preferably below 1140°C.
- 20 6. Method of producing a high-strength sintered body comprising the steps of
- a1) preparing an iron powder except for powder A according to EP 200 691 and diffusion-alloying Ni and/or Mo to the iron powder or mixing metal
- 25 particles of Ni and/or Mo to the iron powder, or  
a2) preparing a melt of iron and molybdenum, water-atomising the melt to a powder and diffusion-alloying Ni to the resulting powder or mixing metal particles of Ni with the powder,
- 30 b) adding carbon to the powder obtained, the amount of the included components being so selected that the resulting powder composition in addition to iron essentially consists of about
- 35 0.5 - 4.5 % by weight Ni  
0.65 - 2.25 % by weight Mo  
0.20 - 1.0 % by weight C,

less than 2% by weight, preferably less than about 1% by weight, of impurities and optionally lubricant,

5 c) compacting the powder composition for obtaining a green body, and

d) sintering the green body whereby the sintering gives essentially the same variation in the dimensional change irrespective of density variations within the range of 6.7-7.5 g/cm<sup>3</sup> in the green  
10 body.

7. Method of producing a high-strength sintered body without the subsequent heat treatment according to EP 334 968, comprising the steps of

15 a1) preparing an iron powder except for powder A according to EP 200 691 and diffusion-alloying Ni and/or Mo to the iron powder or mixing metal particles of Ni and/or Mo to the iron powder, or  
a2) preparing a melt of iron and molybdenum, water-atomising the melt to a powder and diffusion-alloying Ni to the resulting powder or mixing metal particles of Ni with the powder,  
20

b) adding carbon to the powder obtained, the amount of the included components being so selected that the resulting powder composition in addition to  
25 iron essentially consists of about

0.5 - 4.5 % by weight Ni

0.65 - 2.25 % by weight Mo

0.20 - 1.0 % by weight C,

less than 2% by weight, preferably less than about 1% by weight, of impurities and optionally lubricant,  
30

c) compacting the powder composition for obtaining a green body, and

35 d) sintering the green body at a temperature below 1150°C, preferably below 1140°C, whereby the sintering gives essentially the same variation in

the dimensional change irrespective of density variations within the range of 6.7-7.5 g/cm<sup>3</sup> in the green body.

8. Method according to any of the claims 5-7,  
5 wherein, for densities above about 7.3 g/cm<sup>3</sup>, the green product is subjected to presintering and an additional compacting step before the final sintering step.

9. Method according to any of the claims 5-8,  
10 wherein a presintering step is carried out at a temperature between 700 and 850°C.

10. Method according to any of the claims 5-9,  
wherein the sintering is carried out for less than an hour, preferably between 20 and 40 minutes.

11. Method according to any of the claims 5-10,  
15 wherein the compacted powder composition is subjected to a final sintering at a temperature between about 1070°C and about 1150°C, preferably between 1100°C and 1140°C.

12. Sintered products which in addition to iron essentially consist of  
20 0.5 - 4.5 % by weight Ni  
0.65 - 2.25 % by weight Mo  
0.20 - 1.0 % by weight C,  
less than 2% by weight, preferably less than about 1% by weight of impurities, except for products prepared from  
25 the powder A according to EP 200 691 and C, D, E and N of EP 334 968.

13. Low temperature sintered products which in addition to iron essentially consist of  
30 0.5 - 4.5 % by weight Ni  
0.65 - 2.25 % by weight Mo  
0.20 - 1.0 % by weight C,  
less than 2% by weight, preferably less than about 1% by weight, of impurities except for the product prepared from powder A according to EP 200 691.

14. Products which in addition to iron essentially consist of

0.5 - 4.5 % by weight Ni

5 0.65 - 2.25 % by weight Mo

0.20 - 1.0 % by weight C,

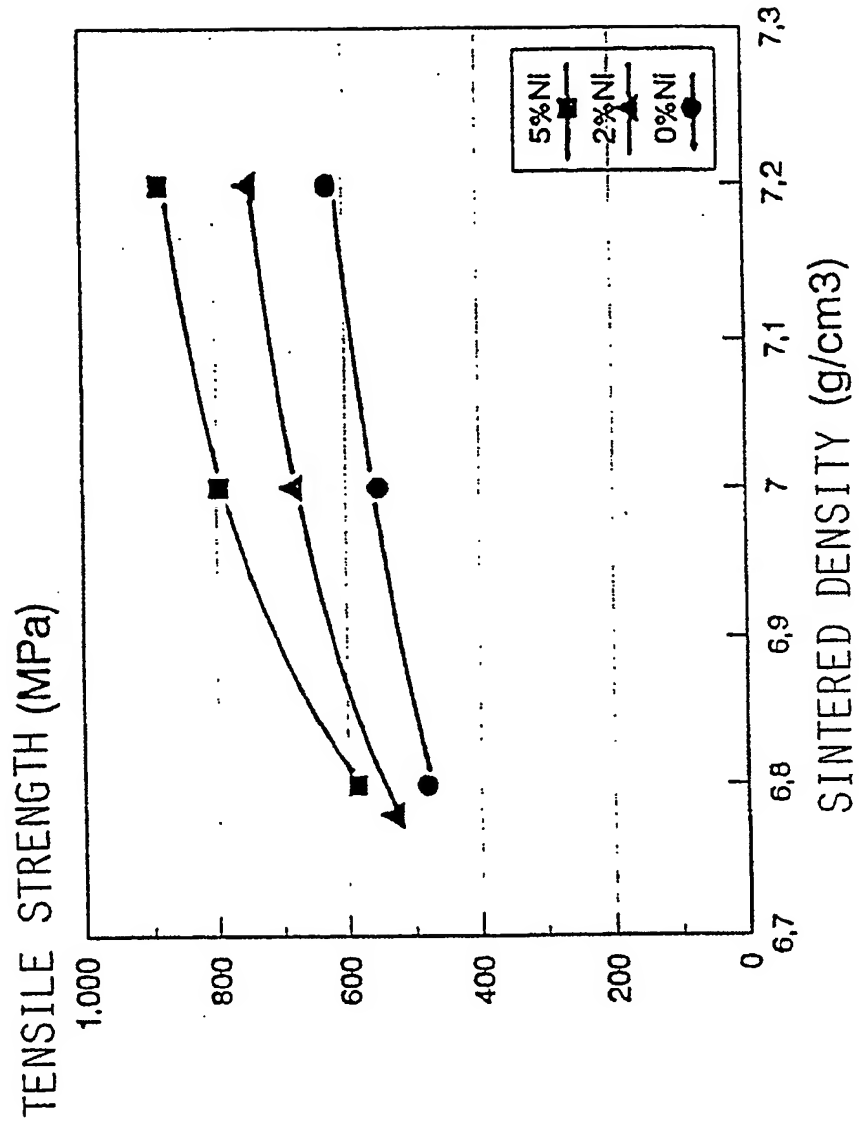
less than 2% by weight, preferably less than about 1% by weight, of impurities sintered at a temperature below about 1150°C and having a tensile strength of about 500-

10 1000 MPa.

15. Use of an iron powder composition according to claim 1 or 2, for the production of high-strength sintered products.

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**Fig.1a**  
TENSILE STRENGTH AS A FUNCTION OF SINTERED DENSITY FOR  
Fe-1,5%Mo-0,5%C AT VARYING Ni-CONTENTS

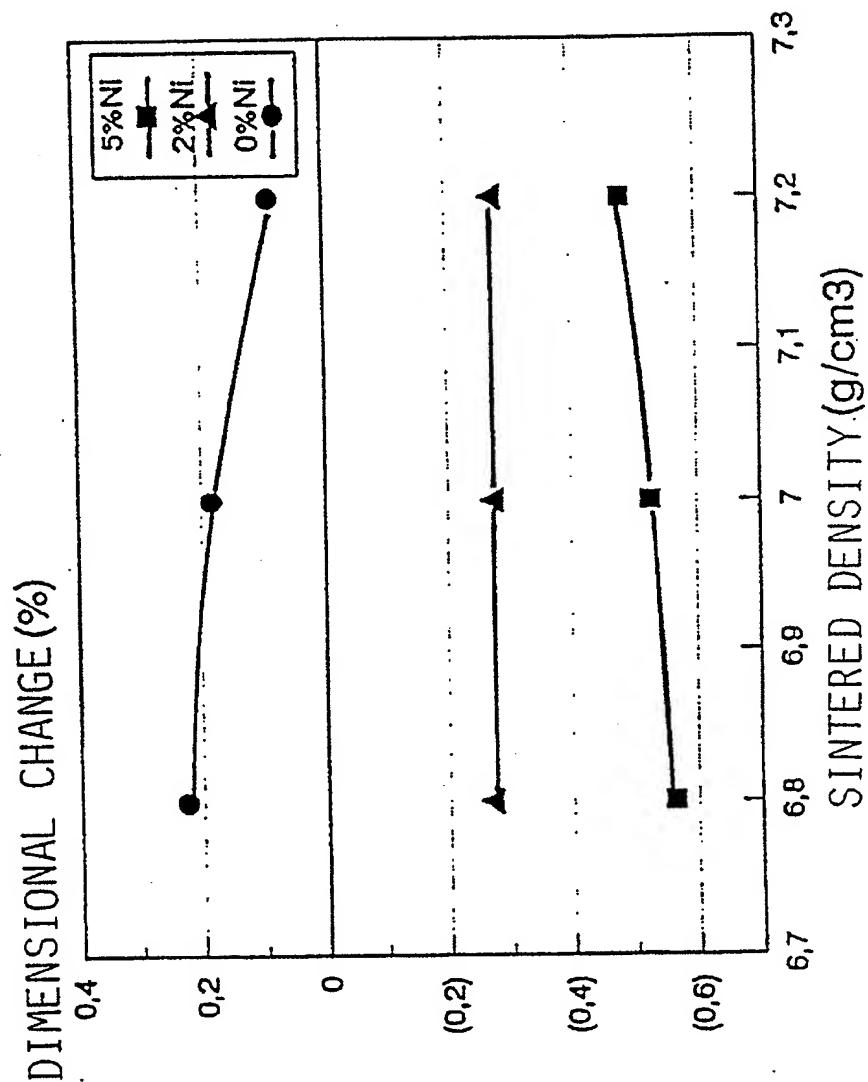


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Fig.1b

DIMENSIONAL CHANGE AS A FUNCTION OF SINTERED DENSITY FOR  
Fe-1,5%Mo-0,5%C AT VARYING Ni-CONTENTS

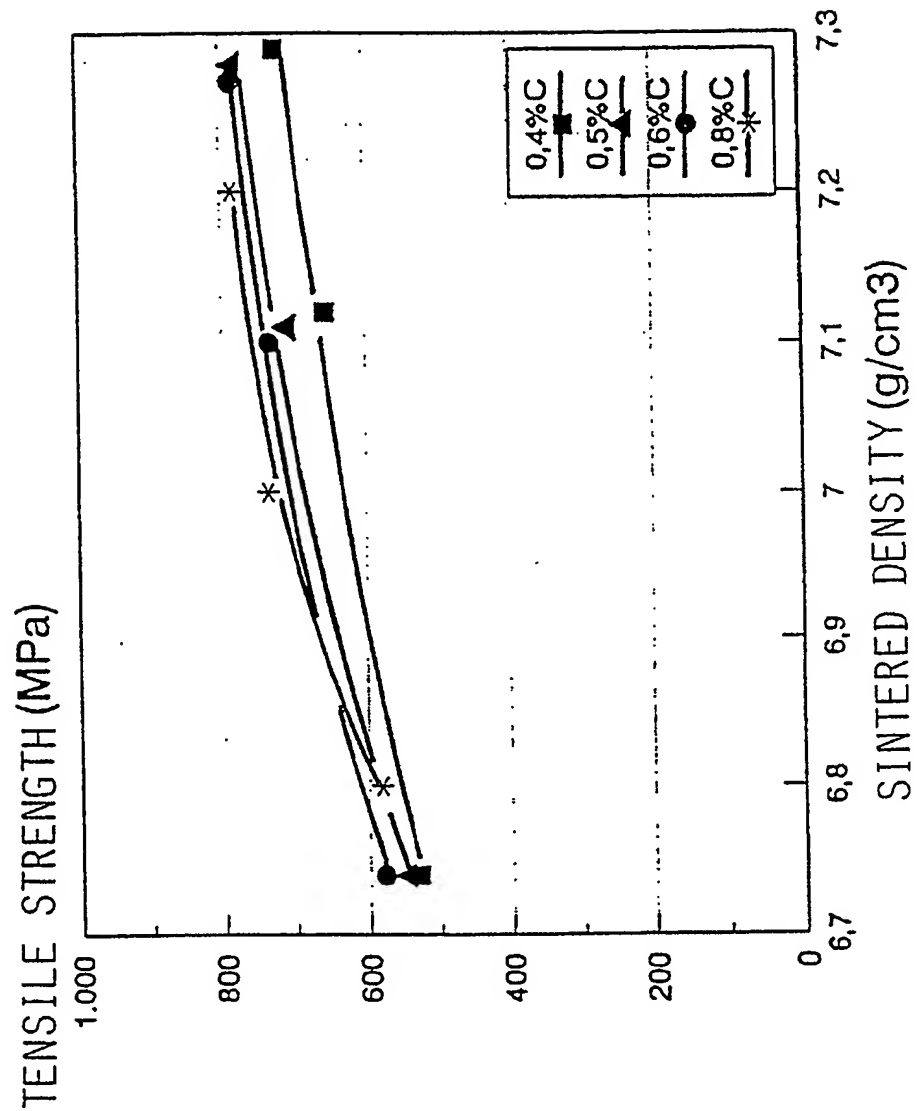


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TENSILE STRENGTH AS A FUNCTION OF SINTERED DENSITY FOR  
Fe-1,5%Mo-2%Ni AT VARYING C-CONTENTS

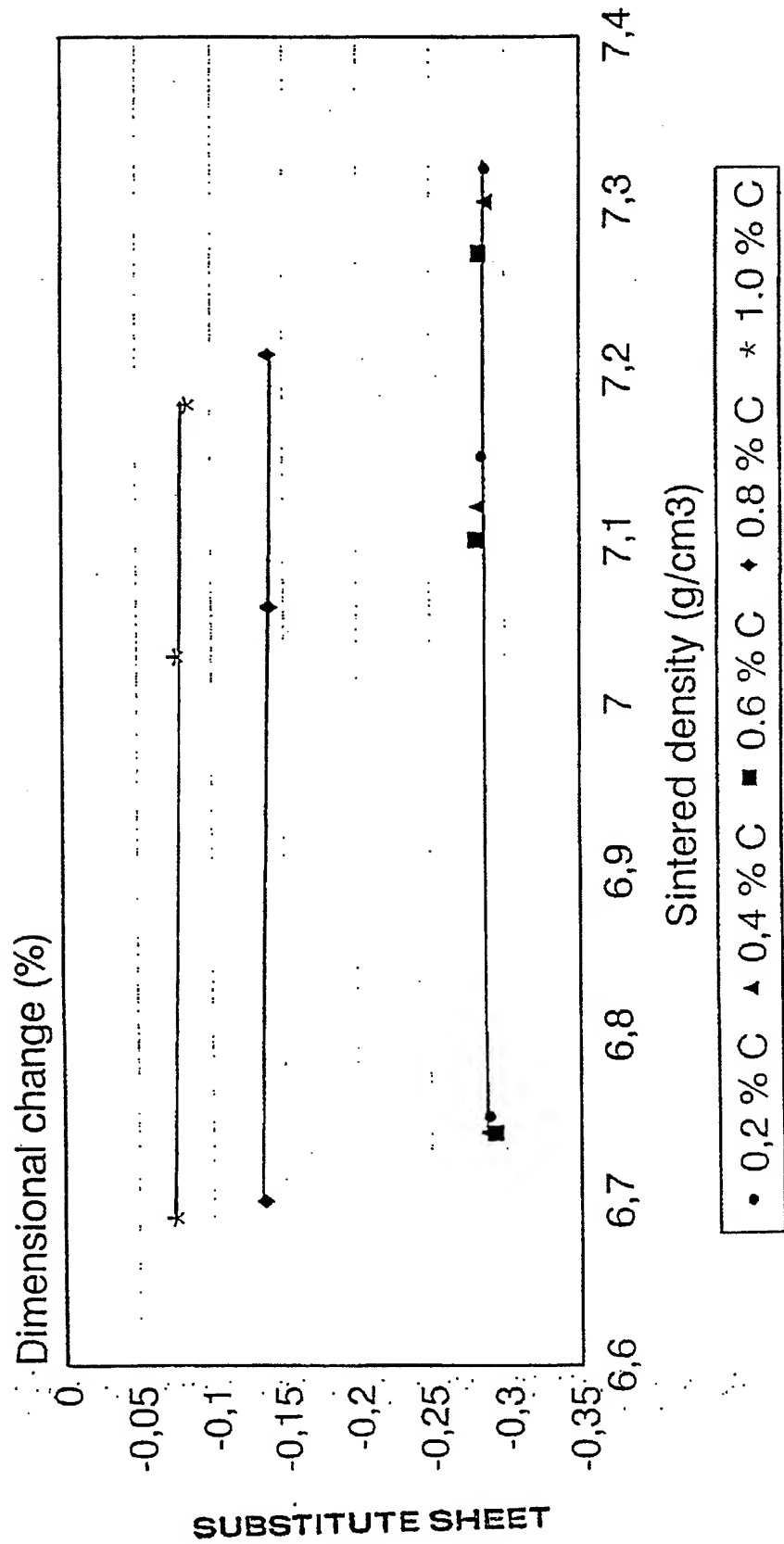
Fig.2a



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Fig. 2b  
Dimensional change as a function of sintered density  
Material C at different carbon contents

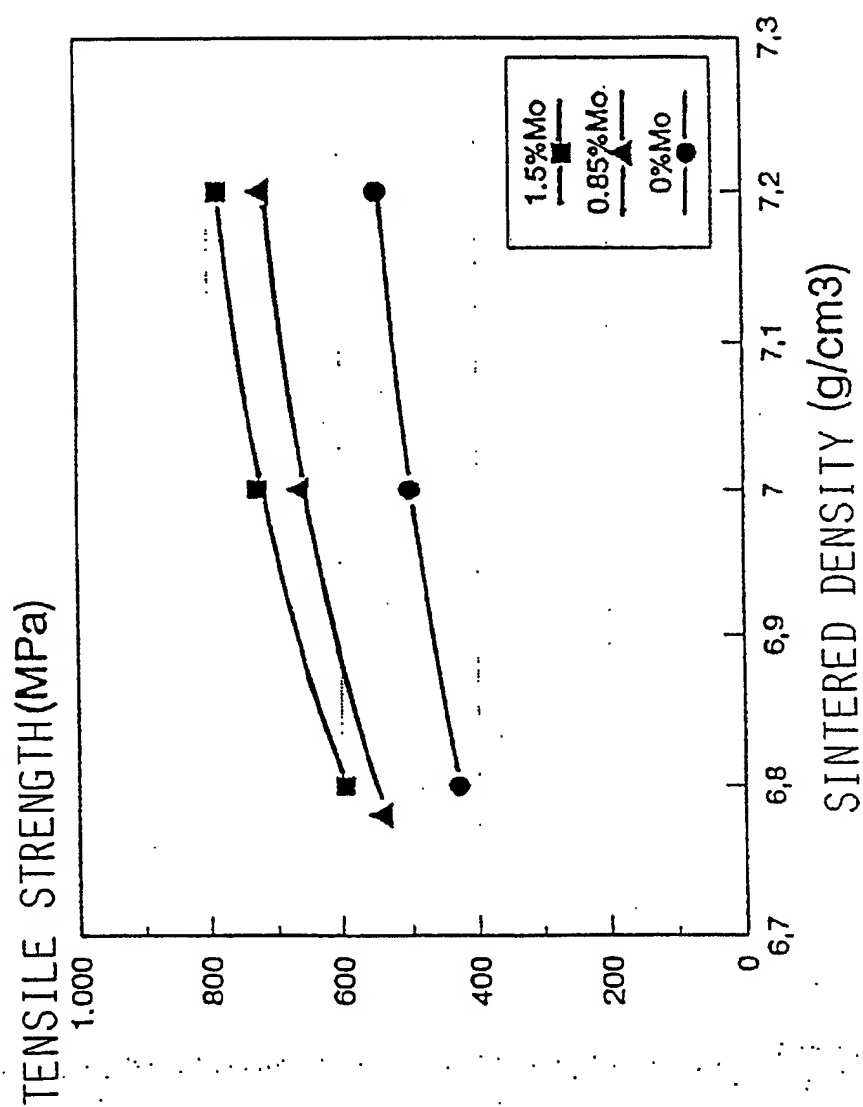




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Fig.3a

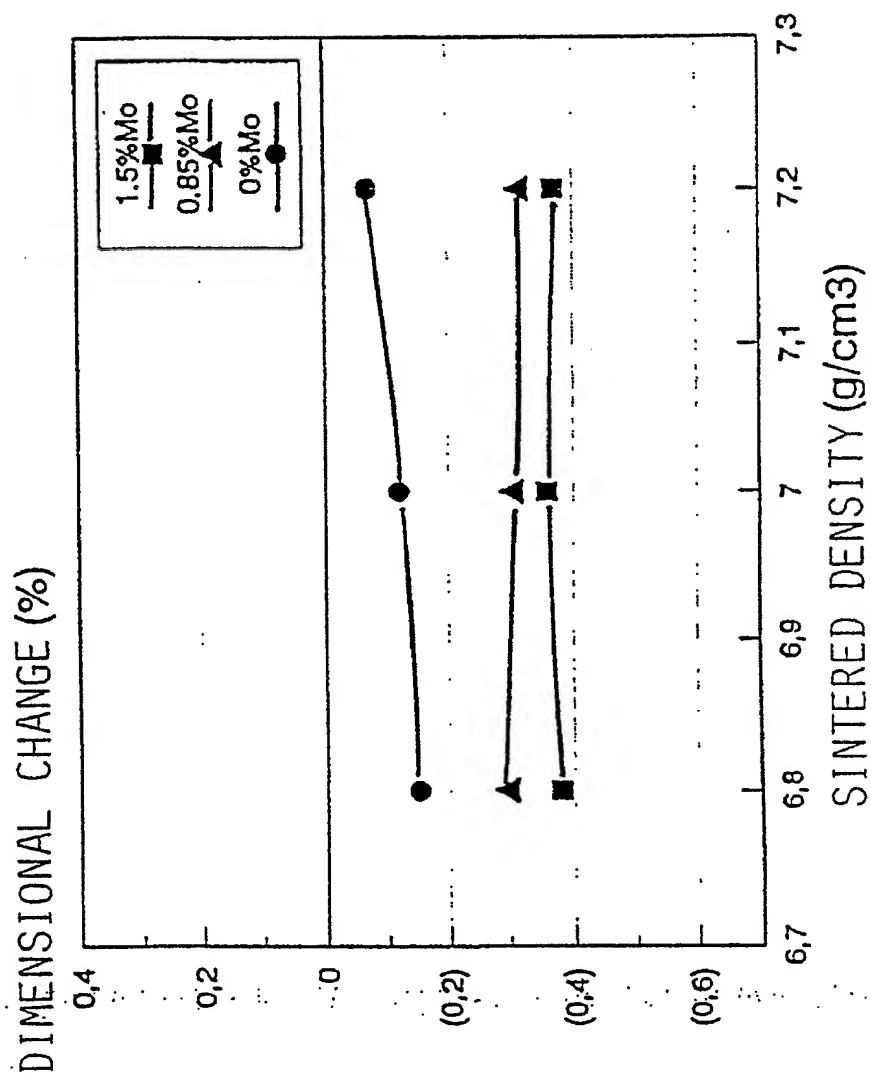
TENSILE STRENGTH AS A FUNCTION OF SINTERED DENSITY FOR  
Fe-2%Ni-0,5% C AT VARYING Mo -CONTENTS



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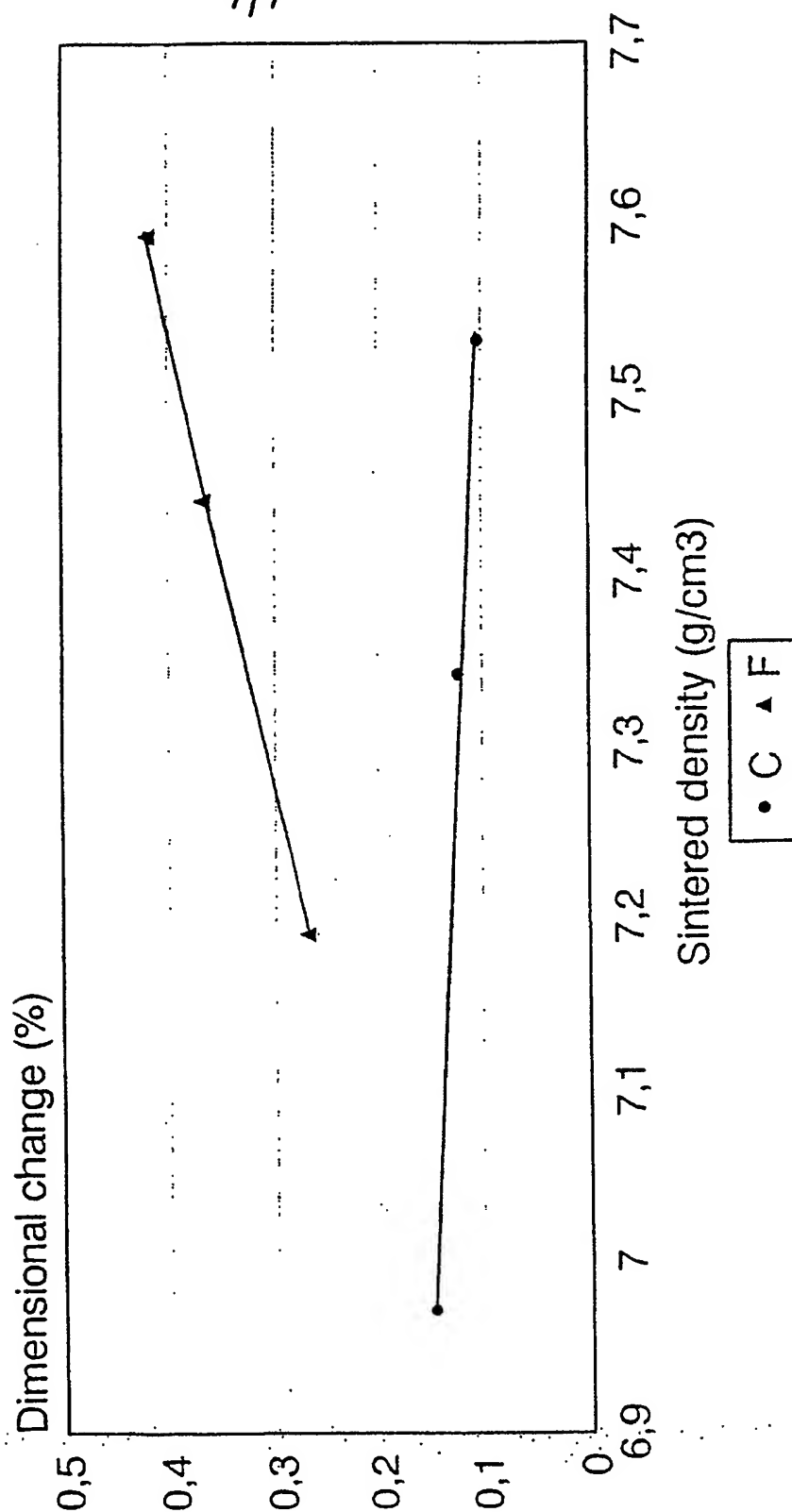
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**Fig.3b**  
DIMENSIONAL CHANGE AS A FUNCTION OF SINTERED DENSITY FOR  
Fe-2%Ni-0,5%C AT VARYING MO-CONTENTS



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Fig. 4  
Dimensional change as a function of sintered density  
Material C and F at a carbon content of 0.5 %



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1  
INTERNATIONAL SEARCH REPORT

International application No.  
PCT/SE 92/00860

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC5: B22F 1/00, C22C 33/02  
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC5: B22F, C22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP, A1, 0200691 (HÖGANÄS AB), 10 December 1986 (10.12.86), column 3, line 5 - column 7, line 27; column 9, line 29 - line 36	1,4,5,9,10, 11
A	---	2,3,6,7,8,12
X	EP, A1, 0334968 (KAWASAKISTEEL CORPORATION), 4 October 1989 (04.10.89), page 10 - page 13; page 21, line 1 - line 8; page 32 - page 36	1,2,4,5,6,7, 8,9,11,12
A	---	3,10

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search 6 July 1993	Date of mailing of the international search report 12 -07- 1993
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Nils Engnell Telephone No. +46 8 782 25 00

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## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE, A, 2112944 (THE BIRMINGHAM SMALL ARMS CO., LTD.), 7 October 1971 (07.10.71), page 2, line 12 - page 4, line 16; page 6	1,2,4,11,12
A	--	3,5-10
A	DE, A1, 4031408 (HITACHI POWDERED METALS CO., LTD.), 11 April 1991 (11.04.91), page 3, line 2 - line 9; page 3, line 34 - line 40; page 5, line 10 - line 19	1-12
E,X	WO, A1, 9222395 (HÖGANÄS AB), 23 December 1992 (23.12.92)	1-12
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**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

28/05/93

International application No.  
PCT/SE 92/00860

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A1- 0200691	10/12/86	JP-A- 61231102	15/10/86
		SE-B, C- 453733	29/02/88
		SE-A- 8501102	08/09/86
		US-A- 4702772	27/10/87
EP-A1- 0334968	04/10/89	US-A- 4954171	04/09/90
		WO-A- 8902802	06/04/89
		JP-A- 2097602	10/04/90
DE-A- 2112944	07/10/71	BE-A- 764155	02/08/71
		FR-A- 2084728	17/12/71
		GB-A- 1305608	07/02/73
DE-A1- 4031408	11/04/91	GB-A- 2237029	24/04/91
		JP-A- 3120336	22/05/91
		US-A- 5049183	17/09/91
WO-A1- 9222395	23/12/92	NONE	

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